The Effects of Natural Capital Investment on Coastal Resilience to Natural Hazards

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Abstract:
Over half of the world's population lives and works near the coast. Climate change poses an increasing inherent risk to coastal communities. Rising sea level and increased frequency and intensity of natural disasters have the ability to decimate coastal infrastructure and economies. Human impacts have changed and caused loss of ecosystem services that serve as natural coastal protections such as mangroves, coral and oyster reefs, and marshes. The loss of these protections results in increased environmental risks. To enhance or replace these ecosystem services, investments in coastal protection, in the form of green or gray infrastructure, can be made. Investment in this infrastructure has been shown to yield economic returns in the form of property values. While coastal adaptations clearly increase property values, it is not entirely sure to what extent coastal adaptation investments affect the economic resilience of a community after a natural hazard, such as a hurricane or flood. Communities that have invested in coastal protections are compared to communities that have not invested in coastal protections with regards to their resilience. This is analyzed by studying how long it takes for coastal property values to recover following a natural hazard. Using a hedonic pricing method which looks at property values, this study aimed to show to what extent coastal adaptation investments affect the economic resilience of a community following a natural hazard. The data from Dare County, NC showed that beach nourishment increases property values and increases resiliency following hurricanes that occur relatively close in time scale to the nourishment. Living shorelines were found to have a significant effect on housing prices but limited observations may call this result into question.

1. Introduction:

1.1.Natural Hazards: An Increasing Economic Concern on the Coast

The effects of climate change are world-wide. Global temperature rise along with increased natural hazards are not confined to a certain region of the world. However, coasts are especially susceptible to the negative effects of climate change. The rise in sea level due to melting glaciers and the increase in storm risk significantly impact coastal communities (Gopalakrishnan, McNamara, Murray, & Smith, 2010). According to the 2005 Millennium Ecosystem Assessment, natural hazards on the coast are increasing in numbers and degree of destruction, measured by loss of human lives, economic loss, ecological damage, and harmed social networks (Costanza & Farley, 2007). Hurricane Katrina and the tsunami in the Indian Ocean exemplify the disastrous impacts of natural hazards economically as well as on humanity over the past couple decades.

This poses a serious concern for humans as over half of the world population lives and works near the coast (Gopalakrishnan et al., 2010). This trend is continuing as more and more people move toward the coast each year (Barbier, 2011). The infrastructure and economic activity that lies within striking distance of coastal natural hazards is vast. Since there is so much activity in coastal areas the fear of coastal destruction has increased (Pompe & Rinehart, 1994).

Human Impact on Nature's Defense Mechanisms

Nature has built in defense mechanisms on the coast that provide protection from natural hazards. Ecosystem services are defined as the benefits people obtain from ecosystems (Barbier, 2011). These benefits can be goods, such as things that are harvested, cultural, such as spiritual and heritage values, or service related, such as regulatory and protective functions. This paper will focus on service related benefits that coasts are able to provide such as storm protection, flood control, and erosion resistance. There are many examples of ecosystem services on the coast. Many ecosystems on the coast are able to stabilize and protect communities near the ocean by reducing wave height (Gedan, Kirwan, Wolanski, Barbier, & Silliman, 2010). Mangroves provide natural barriers to coastal storms. In a 1999 cyclone in India they reduced the number of deaths by 1.72 per village and reduced damage to livestock and agriculture. In communities with the mangroves there was a $33 loss per household as compared to a $154 loss per household in communities without their protection (Barbier, 2011). Coral reefs provide a marine barrier of sorts from weather that causes large tides and wave activity. This protects human lives, property, and economic investment in infrastructure. Saltwater marshes protect the coast from storm damage as well. A study on the economic damages of 34 US hurricanes occurring after 1980 found that saltwater marshes accounted for a 60% decrease in damages from the hurricanes (Barbier, 2011). While coastal protection by ecosystem services is not consistent in all locations, it is clear that ecosystem services do protect the coast from damage to some extent.

Human induced loss and change of coastal ecosystems has taken away some of the ecosystem services that provide these protections to coastal populations. Humans have already caused massive destruction of coastal ecosystems as 50% of marshes, 35% of mangroves, 30% of coral reefs, and 29% of sea grasses have been lost or degraded (Barbier, 2011). These are all ecosystems that provide large benefits in the form of coastal protection. Decisions that humans make with regards to the destruction of ecosystems for economic gains have increased the risk of natural hazards near the coast (Costanza & Farley, 2007). Human decisions and actions, such as land use change causing erosion and human caused climate change and sea level rise, increase the probability and severity of natural hazards such as floods and hurricanes (Klein, Nicholls, & Thomalla, 2003).

2. Non-market Valuation of Coastal Amenities and Risks

2.1. Valuing Ecosystem Services and Coastal Protection: Hedonic Pricing Method

Natural ecosystems are economic assets and need to be valued as such. Since the ecosystem services in question are indirect use values, namely flood control storm protection, and decreased erosion, they are difficult to value and are not present in the market (Barbier, 2011). These services are vital to the economy that lives on the coast. However, these services do not have a direct market value. Non-market valuation methods in environmental and natural resource economics enable indirect recovery of the value of ecosystem services for a benefit-cost analysis of decisions that the market does not normally take into account such as conservation and development of ecosystems.

By taking natural, social, and human capital into account rather than just built capital, society can move toward a more sustainable use of resources. Many ecosystems that once provided valuable services are deteriorated as previously mentioned. However, with the valuation of indirect use values, such as ecosystem services that provide storm and erosion protection, there is an increased focus on putting a price on services that nature provides. While it may be too late to conserve ecosystems that are valuable in some locations, rebuilding these services is still in the scope of possibilities. Investment in these services mainly aims to reduce susceptibility to effects of climate change and other natural hazards prior to them occurring (Klein et al., 2003).

Many studies use a benefit-cost analysis to determine whether conservation or investment into the recreation of ecosystem services is economically responsible. A popular method to value ecosystem services is the hedonic property value method, where the effects of investments in coastal adaptation on property values are analyzed. A hedonic price function decomposes the price of a residential property into different structural attributes, such as bedrooms, square footage, stories, age, neighborhood characteristics, and environmental attributes, such as the living systems in the area. These attributes act as independent variables while the price is the dependent variable in the regression. Then the coefficient on the variable of interest is examined to determine the marginal effect of an attribute on housing values.

The hedonic pricing method can also be used to analyze the effects that erosion, floods, and storms on property values. These effects can be seen as housing markets capitalize the impact of coastal risks. Benefit-cost analyses of coastal adaptation investments such as beach nourishment and living shoreline projects can guide decisions on investments. The effectiveness of these investments against flooding and erosion effects property values (Bin, Kruse, & Landry, 2008). Generally, investment in coastal adaptation raises property values while flood and erosion risk decrease property values (Roebeling, Coelho, & Reis, 2011). A benefit-cost analysis must be employed to determine whether the benefits of investment outweigh the costs of that investment by decreasing storm, flood, and erosion hazard. It must also be determined where the benefits are mostly accrued and where they are not as significant.

Coastal amenities such as beach width, break walls, wetlands, and levees provide public goods through storm, flood, and erosion protection, in addition to recreational benefits that some of them create (Landry & Hindsley, 2011). By using a hedonic property value method, these benefits are able to be quantified in the form of property value increases due to decreased risk of storm damage, flooding, and erosion.

2.2.Coastal Adaptations and Economic Value

Investments in coastal adaptations make economic sense when the benefits outweigh the costs. Rationalization of investment in coastal protection and ecosystems depends on a benefit-cost analysis of those investments (Spurgeon, 1999). Location within flood zones or areas that are highly vulnerable to natural hazards lowers property value. There are numerous studies that find that investments in coastal adaptations increase property values. Most of these studies utilize the hedonic property value method to determine the change in economic value after an investment is made.

Conservation and land use restrictions also affect housing prices. Maryland instituted a policy where land near the coast experienced development restrictions and requirements (Parsons, 1992). Changes in housing prices before the restrictions were in place were compared with housing prices after the restrictions were in place using the repeat sale method. There was a definite rise in housing prices in the restricted area due to decreased availability of land and increased amenities due to the environmental protections put in place (Parsons, 1992).

Landry et al. (2003) compared three different practices that could be implemented with regards to coastal erosion management, beach nourishment, beach nourishment (widening beaches) with shoreline armoring (rip rap, sea walls, etc.), and retreat (letting coastlines erode naturally since erosion is inevitable) (Landry, Keeler, & Kriesel, 2003). Comparing alternative adaptation strategies, they examine whether increasing beach width was the best approach to take with regards to coastal management. Through a 25-year simulation of a community in Georgia, with a focus on property values effects, they concluded that shoreline armor is not optimal since it is expensive and harms the aesthetics of property. Erosion rate plays a large factor in deciding which method to use. If the erosion rate is fast and nourishment exacerbates the forces causing the erosion, then retreat is optimal. If nourishment is somewhat effective, then the benefits will likely outweigh the costs as economic activity can continue in the area (Landry et al., 2003).

Reliable benefit-cost analyses of coastal adaptation investments are the first step in evaluating and justifying long-term policies (Spurgeon, 1999). There are numerous studies that find that investments in coastal adaptations increase property values. Coastal adaptation through widening beaches, which offer storm and erosion protection, increase property values

(Gopalakrishnan, Smith, Slott, & Murray, 2011). These property values increase due to the decreased natural hazard risks (Gopalakrishnan, McNamara, Murray, & Smith, 2010). Further, increased natural hazards in the form of sea level rise and an increase of storms can drive the demand for protections up (Gopalakrishnan et al., 2010).

Beach width accounts for a much larger part of property value than previously assumed (Gopalakrishnan, Smith, Slott, & Murray, 2011). Wider beaches, which offer storm and erosion protection, affect housing prices. Beach erosion decreases property values while adding beach width increased property values. Aside from natural hazard risks, erosion has a large impact on coastal property values (Gopalakrishnan et al., 2010). Adding beach width increases property value at a diminishing rate, i.e. less increase in property value as more width is added (Pompe & Rinehart, 1994). Houses closer to the beach see greater returns with regards to their property values as beaches are widened. Intervention often occurs in an effort to stabilize a shoreline. By replacing eroding sections of beach with sand from another location beach nourishment stabilizes a shoreline. Costs exist in the form of construction, maintenance, and environment. Hedonic pricing method studies consistently show that wider beaches and decreased natural hazard risks increase coastal property values (Gopalakrishnan et al., 2010). This is exemplified by studies that show that wider beaches and towns with nourishment projects have increased property values. Beach and dune width has a significant positive effect on property values within 300 meters of the shoreline (Landry & Hindsley, 2011). Property values align closely with stabilized, wide, beaches. Increased natural hazards in the form of sea level rise and an increase of storms can increase the demand for erosion protection (Gopalakrishnan et al., 2010).

Aside from nourishment practices, a combination of coastal adaptation approaches can also be used so that man-made structures and ecosystems work together in ways that mirror nature and can better protect a coast (Gedan et al., 2010). “Living shorelines” provide the benefits of traditional coastal adaptations such as break walls with the benefits of ecosystem restoration. An example is oyster domes and reef balls. These are concrete structures that decrease wave size while also creating a habitat for marine life in combination with wetlands. The pairing is able to more effectively combat waves and prevent erosion than traditional approaches, or any one on their own (Gedan et al., 2010).

These conclusions do come with caveats. The National Flood Insurance Act of 1968 subsidizes coastal property owners as the federal government covers a large portion of flood insurance and cleanup and reconstruction costs after a flood. Since property owners do not have to cover the full cost of storm damages the benefits that wider beaches provide in the form of storm protection are most likely undervalued (Atreya et al., 2015). The greater the probability of damage from storms the greater the value of wider beaches (Pompe & Rinehart, 1994). This is important in this field of study as it shows that coastal adaptations will not yield equal economic returns everywhere. The risks in an area affect the value of coastal adaptations. The relationship between property values and beach width, or coastal adaptation investments, is also difficult to discern since there is variability in people's knowledge and understanding of natural erosion, effectiveness of coastal adaptations, and management practices (Landry & Hindsley, 2011).

Additionally, the difference in price effects after a natural disaster is diminishing. While prices decrease following a natural disaster, they rebound eventually. Price differences disappear about 5-6 years following a major natural hazard (Bin & Landry, 2013). A change in people's risk perceptions with the prevalence of an event and a lack of homebuyers' knowledge regarding natural hazard risks may account for this difference (Bin & Landry, 2013). This change in risk perception and prevalence of the event will be taken into account. Control communities, communities outside the strike zone of a hurricane, and communities without coastal adaptations in the strike zone of a hurricane, will account for these unintended variables.

While short term beach nourishment can pass a benefit-cost analysis, long term nourishment as an infinite solution is not a good adaptation to climate change (Gopalakrishnan et al., 2010). Coastal adaptations make communities more resilient to natural hazards as long as the protections are not breached. Coastal adaptations often lead to a false sense of safety in a coastal region which causes increased economic growth in the short run but potential large losses in the long term (Travis Franck, 2009). Coastal adaptations cannot necessarily stand the test of sustained and continued climate change and the effects that follow.

Parsons and Nailly looked at the cost of beach nourishment and who should be paying for it given the benefits are not equally distributed. Most beach nourishment projects are federally funded, thereby tax funded. Since property owners closer to the beach receive larger benefits from beach nourishment they should pay taxes that go towards beach nourishment in proportion to the benefits they receive (Parsons & Noailly, 2004). Using a hedonic price function Parsons and Noailly were able to create a property tax schedule so that the tax burden and the beach nourishment property value benefits were more closely related. They argued that this is important so that people pay the real cost of living on the beach and protecting and improving their property.

In conclusion, even when coastal erosion or flooding is inevitable, it may be worth investing in coastal adaptation measures as benefits of temporary protection may outweigh the costs (Roebeling et al., 2011).

2.3.Resilience to Natural Hazards

Resilience is defined as the "ability to cope with and recover from external shocks. Systems that undergo stress and have the ability to recover and return to, or past, their original state are resilient," (Klein et al., 2003). Adaptation can take many forms: decreasing human activity in natural hazard prone areas to protect ecosystems services, changing location of economic and human activity, assisting ecosystems by helping them thrive, and increasing the infrastructure in a system so that it can better withstand natural hazards (Klein et al., 2003).While there are many options to dealing with natural hazards there is a tendency for people to attempt to reduce their losses through increased infrastructure since there is already a large population and high economic activity near the coast (Klein et al., 2003). By investing in coastal adaptation communities are planning for and adapting to natural hazards by being proactive.

A potential problem with coastal adaptation is that people tend not to make them prior to a large natural hazard. Adeniyi et al. (2016) find that many investments in natural hazard resilience are made after a large natural hazard (Adeniyi, Perera, & Collins, 2016). Bin and Landry echo this thinking with a hedonic valuation study done on risk premiums for property in flood zones. Before a large storm there is no difference between the price of a house in a flood zone and one that is not, but after a natural hazard there are significant price differences (Bin & Landry, 2013). Houses in the flood zone after a natural hazard experience a decrease in value. This effect is diminishing as the price differences go away about 5-6 years following a major natural hazard as houses in flood zones recover their lost value. A change in people's risk perceptions with the prevalence of an event and a lack of homebuyers' knowledge regarding natural hazard risks may account for this difference (Bin & Landry, 2013). Being closer to the time of a natural hazard occurring may cause people to perceive the risk more clearly. As time passes and the natural hazard is further in the past, people may perceive the risk less clearly and it may not be as prevalent for them.

While coastal adaptation clearly increases property values, it is not clear to what extent coastal adaptation investments affect the economic resilience of a community after a natural hazard. The impact of natural capital investments on the vulnerability or resilience of communities over time remains unexplored. Investments in coastal protection, in the form of green or gray infrastructure, can reduce communities' susceptibility to the effects of climate change and other natural hazards prior to them occurring (Klein et al., 2003). If the economic benefits of coastal adaptation are noted, then communities have better information to make investment decisions and be more likely to preemptively invest in coastal adaptations.

Building on the prior literature, in this thesis, I examine the question of whether natural capital investment, investment in coastal adaptations that protect against natural hazards, in coastal communities' increases their resilience to, or economic "bounce-back" after, natural hazards. It is hypothesized that communities that invest in coastal protection have high resilience, and therefore will see their property values return to pre-disaster levels quicker than communities that did not invest in coastal protection. Communities that have invested in coastal protections must be compared to communities that have not invested in coastal protections with regards to their economic resilience, their property value recovery. This can be analyzed by studying how long it takes for a coastal economy to recover following a natural hazard. I use a hedonic pricing model to study the impact of coastal adaptation investments on economic resilience, reflected through housing markets, of a community following a natural hazard. Housing markets can be a reliable signal of economic development in regions that rely largely on tourism. Therefore, I focus on the coastal county of Dare, North Carolina to specifically examine the economic impact of investments in beach nourishment and living shorelines. Dare, North Carolina has accessible country tax accessor data on property values and accompanying property characteristics. Dare also contains communities that have invested in beach nourishment and living shoreline projects over the past couple decades. Additionally, Dare has experienced natural hazards in the form of hurricanes in that same timeframe.

This research can provide policy insight to evaluate the impact of environmental investments over time. While the proposed research focuses on climate adaptation along the U.S. Atlantic Coast, implications of this work are applicable to other problems and locations around the world. Coastal infrastructure investments can all be guided by this study which will look into the return on those investments when disasters occur. Studies that show the economic benefits of these investments can guide these decisions.

In the following section, I describe the econometric methods, data used, and study area for the analysis. I will then describe the estimation results and analyze them. Finally, I will discuss the broader implications of the results of the study and work that could be done in the future to expand on what has been found.

3. Framework and Methodology

3.1.Hedonics Pricing Method

Economic resilience is compared in communities that have invested in coastal protections and communities that have not invested in coastal protections. Coastal protections are defined as beach nourishment or living shoreline projects for the purpose of this paper. These are the two main coastal protections that Dare has instituted. Resilience is defined as how long it takes for a coastal economy to recover following a natural hazard. A hedonic pricing method will be used to compare the time it takes property values to recover in a community that invested in coastal protections to a community that did not invest in coastal protection. The Hedonic Pricing Method is a revealed preference method. Revealed preference methods infer the value people place on natural resources by examining behavior in the market for related goods. The hedonic method specifically looks at how much people pay for housing in different locations and/or at different times. It decomposes the value of a property into its attributes and infers the implicit price of the attributes (including environmental attributes). The attribute in question will be the community's investments in coastal protections. A standard OLS regression is used to determine the effects of investment on resilience. I estimate the following equation to recover the effect of investment decisions in coastal adaptation:

$$\ln P_{ijt} = \alpha_0 + \alpha_1 X_i + \beta_1 Nourish + \beta_2 OFx\ PostNourish + \beta_3 Living + \beta_4 OFx\ Living + \eta_j + \xi_t + \varepsilon_{ijt}$$

P_{ijt} is the sale price of property i in location j sold in year t. X_i includes structural attributes of the property such as age of the structure, living area, numbers of bathrooms, number of stories, elevation. $Nourish$ is an indicator variable that takes the value of 1 if a house is located in the nourished beach, and 0 if located in an unnourished town. This controls for the baseline differences in average housing values between regions that invested in beach nourishment (treated) during the study period and those that had not invested in beach nourishment (control). $Living$ is an indicator variable for a region that has invested in the living shorelines program. To control for unobservables, I include spatial fixed effects (η_j) that control for time-invariant unobservable factors that affect housing values at the subdivision level. I also control for baseline trends in housing prices by including year fixed effects and seasonal trends by quarter (ξ_t).

3.2.Data:

In this study, I focus on coastal communities in Dare County, North Carolina. Data on housing transactions and structural property characteristics is obtained from publicly available databases through the Dare County tax assessor's website (Dare County Tax Assessor, 2017). The data include single family homes sold in Dare County over the time period 2002-2016. It includes figures on sale date, sale price, square footage, bedrooms, bathrooms, stories, age, whether it is ocean or sound front, elevation, and distance to the ocean and sound. The summary statistics are shown in Table 1.

Data on beach nourishment is collected from the Program for the Study of Developed Coastlines (PSDS) database maintained by Western Carolina University (Western Carolina University, 2017). Data on living shorelines is collected from a database maintained by the North Carolina Coastal Federation (North Carolina Coastal Federation, 2017). Data on the hurricanes evaluated in the study is obtained from the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center Database (NOAA, 2017).

Based on the beach nourishment data, there was one shoreline protection beach nourishment project that fell within the time and location of this study. That was a $36,000,000 project completed in 2011 in Nags Head. It was a nourishment of 52,800 feet of beach length and 4,600,000 cubic yards of beach (Western Carolina University, 2017). Based on the living shoreline data, there was one shoreline project that fell within the time and location of this study. That was a $112,173 project completed in 2010 in Nags Head. The living shoreline is a length of 725 feet and covers an area of 1.5 acres (North Carolina Coastal Federation 2017). The location of the beach nourishment and living shoreline that were studied can be seen in Figure 1.

4. **Estimation Results**

A semi-log hedonic price function was estimated using log of the sale price of each home as a dependent variable. Log price was used (rather than price) to ease interpretation of the results, as coefficients now reflect percentage-change in housing values associated with changes in covariates. The independent variables include square footage, bedrooms, bathrooms, stories, age of the property, whether it is ocean or sound front, elevation, and distance to the ocean. Then, dummy variables were added to account for a number of factors including whether the town the house was located in had undergone beach nourishment or had introduced a living shoreline and also to account for whether the observation was before or after both Hurricane

Sandy in 2012 and Hurricane Arthur in 2014. Additionally, fixed effects were used to account for the city the property was located in, the subdivision, and sale year. These fixed effects control for common price trends and for time invariant unobservable factors that influence housing markets at the subdivision scale. Then a difference-in-differences approach was taken in order to compare control and treatment groups. The variables that were interacted include nourishment or living shorelines, ocean front or sound front, and Hurricanes Sandy and Arthur.

I estimate the model with three specifications.

The results are shown in Table 2. Since the log price is the dependent variable, each coefficient on an independent variable shows the percentage change in price as a result in an increase of one unit of the independent variable. All of the characteristics of homes and properties that were included had the expected sign and were statistically significant. The constant was 11.88 which computes out to $144,350.55.

There were many characteristics that increased the value of the home: increased number of bedrooms, increased number of stories, increased square footage, increased number of bathrooms, the home being ocean front or sound front, the home being closer to the shore, the home being newer, a home being ocean front and the beach being nourished. There were some characteristics that decreased the value of the home: increased elevation and ocean front homes in the city that had a living shoreline. An additional bedroom increases property value by 3.2%, an additional story by 12.0%, an additional square foot by 0.017%, an additional bathroom by 2.86%, an additional 10 meters from the shore by -0.065%, an additional year old by -0.48%, and an additional foot in elevation by -0.61%. An ocean-front property was found to be 23.8% higher in price than a non-ocean front one, and a sound front property was found to be 38.8% higher in price than a non-sound front one. Properties in towns that underwent beach nourishment had no significant effect. Properties in towns that underwent a living shoreline creation show a decrease in property value by 5.88%. A significant effect was found for properties that are oceanfront and their town experienced either beach nourishment or the installation of a living shoreline. An ocean-front and nourished property increased in value by 18.1% while an ocean-front and living shoreline property decreased in value by 16.3%. The interaction between sound-front properties and living shorelines came up as insignificant. Examining the Hurricane Sandy effect, ocean-front and beach nourished properties experienced a 5.2% increase. All interactions that included Hurricane Arthur resulted in insignificant results.

4.1.*Discussion***:**

This study aims to examine the significance of investment in beach nourishment and investment in living shorelines and also took into account the impact these investments had on home values after hurricanes.

Ocean-front homes showed a significant positive increase in price in areas where beach nourishment had occurred. The coefficient ranged from 16.8% to 20.3% between the three different specified regressions (no hurricane, hurricane Sandy, and hurricane Arthur). Intuitively, this makes sense since ocean-front homes are the ones most impacted by beach nourishment. The nourishment is taking place adjacent to these properties, so the effects are much stronger than for homes not on the ocean or next to the beach. These results show that an investment in beach nourishment certainly has positive consequences for property values that are near the nourishment. Whether these consequences are because of an actual increase in storm protection or merely a perception of increased protection is unknown.

Ocean-front homes showed a significant negative decrease in price in areas where a living shoreline had been constructed. The coefficient ranged from -14.6% to -16.3% between the three specified regressions (no hurricane, hurricane Sandy, and hurricane Arthur). While this result seems counter-intuitive at first glance, this could reflect the fact that, in the study area, the living shoreline was constructed on a sound, not ocean facing. However, the significant negative impact on ocean-front homes is unexpected and may capture other unobservables correlated with the location of living shorelines. Additionally, there was no significant impact on price for sound-front homes in areas where a living shoreline had been constructed. This is unexpected since the sound front homes would be closer to the actual living shoreline. Living shorelines did not have a significant impact on any property values after hurricanes. The results pertaining to living shorelines could be due to a number of factors. For one, there are very few observations in this category. There are only 39 observations that are ocean-front and near a living shoreline and only 10 observations that are sound-front and near a living shoreline. This number of observations makes it hard to derive statistically sound results pertaining to the effects of living shorelines. Second, the living shoreline investment was only $112,173. This is less than a third of the price of the average home in the study. The impact of this relatively small investment may simply not be that large. Additionally, the living shoreline that was constructed was 725 feet of shoreline and covered 1.5 acres. This area is pretty small and consequently may not provide much protection. Further, since the living shoreline was constructed on the sound it may not provide as much protection from storms as beach nourishment on the ocean since much of the heavy damage occurs directly on the ocean, not on a sound where land already provides a buffer from the eye of the storm. Additionally, living shorelines do not provide the same type of property benefit as beach nourishment does. Beach nourishment results in a wider beach that can be used. Living shorelines essentially result in a protected wildland.

After Hurricane Sandy, which occurred in 2012, a year after nourishment took place, ocean-front homes in nourished areas experienced a 5.16% increase in sale price that was statistically significant. The impact that nourishment had on an ocean-front property's value in the area of nourishment can be seen in Figure 2. Figure 2 breaks down the percentage increase on a property's value for properties that are ocean-front and in a nourished area and for properties that are ocean-front and in a nourished area following Hurricane Sandy. Since the actual benefits of the nourishment's impact on storm protection are not measured, this can only be shown as a perceived benefit of the nourishment. These results match the expectations set by Bin and Landry, 2013 which found that people's risk perceptions following a natural disaster impact their purchasing prices. This study shows that the perceived decrease in risk that a nourished beach provides results in an increase in purchase price.

After Hurricane Arthur, which occurred in 2014, three years after nourishment took place, beach nourishment had no statistically significant effect on sale prices after the hurricane. This could be due to the decreasing value of nourishment. At three years out, the nourishment may not have an impact on people's perceptions of protection from natural disasters. The value of nourishment appears to be of diminishing significance over time. Additionally, there were limited observations post-Arthur since the study only included sale dates up to June 2016, which was less than two years after Arthur.

5. Conclusion:

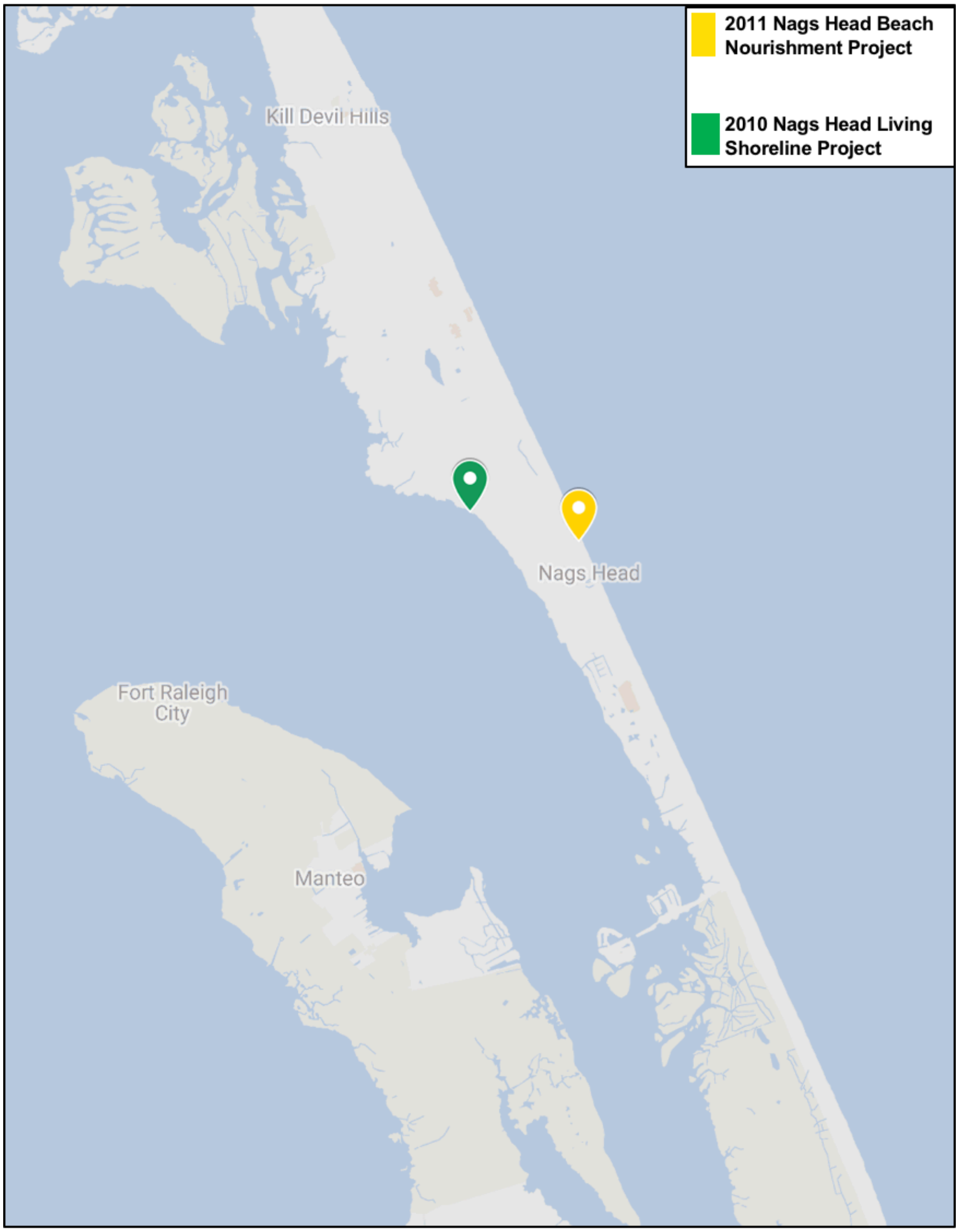
This study confirmed investments in beach nourishment raise the value of ocean front homes in the town where the nourishment takes place. This information is helpful for local governments and citizens when making decisions on community investments in protection and nourishment. However, investment in living shorelines were not found to raise the value of ocean front or sound front homes where the nourishment takes place in this study. Part of this discrepancy could be due to the fact that the investment in beach nourishment is 320 times as much money as the investment in living shorelines. A more robust living shoreline may provide higher benefits. Additionally, the observations for living shorelines are limited. Based on these results, investment in beach nourishment yields a higher return on investment than living shorelines.

This study also found that after a hurricane (Hurricane Sandy in 2012), properties that are ocean-front near nourishment experience an increase in their sale price. This leads to the conclusion that beach nourishment does increase the resiliency of a property. However, this same effect was not found for sale prices following Hurricane Arthur in 2014. This leads to the conclusion that the benefits of beach nourishment, the resiliency that is had, diminishes over time.

There were limitations of this study. For one, Dare, NC has limited instances of beach nourishment projects. Additionally, there were limited number of living shoreline projects without any one being very robust in terms of area or investment dollars. Having further examples of these investments at different years, both close to and further from the time that a hurricane occurs, would yield results that are less case based.

Tables and Figures:

Figure 1: Dare County, NC Coastal Infrastructure Projects 2002-2016



Map of Dare Counry, NC.
Source for the site locations: Google Maps, NC Coastal Federation, Western Carolina University

Figure 2: Impact of Nourishment on Ocean-Front Property Value

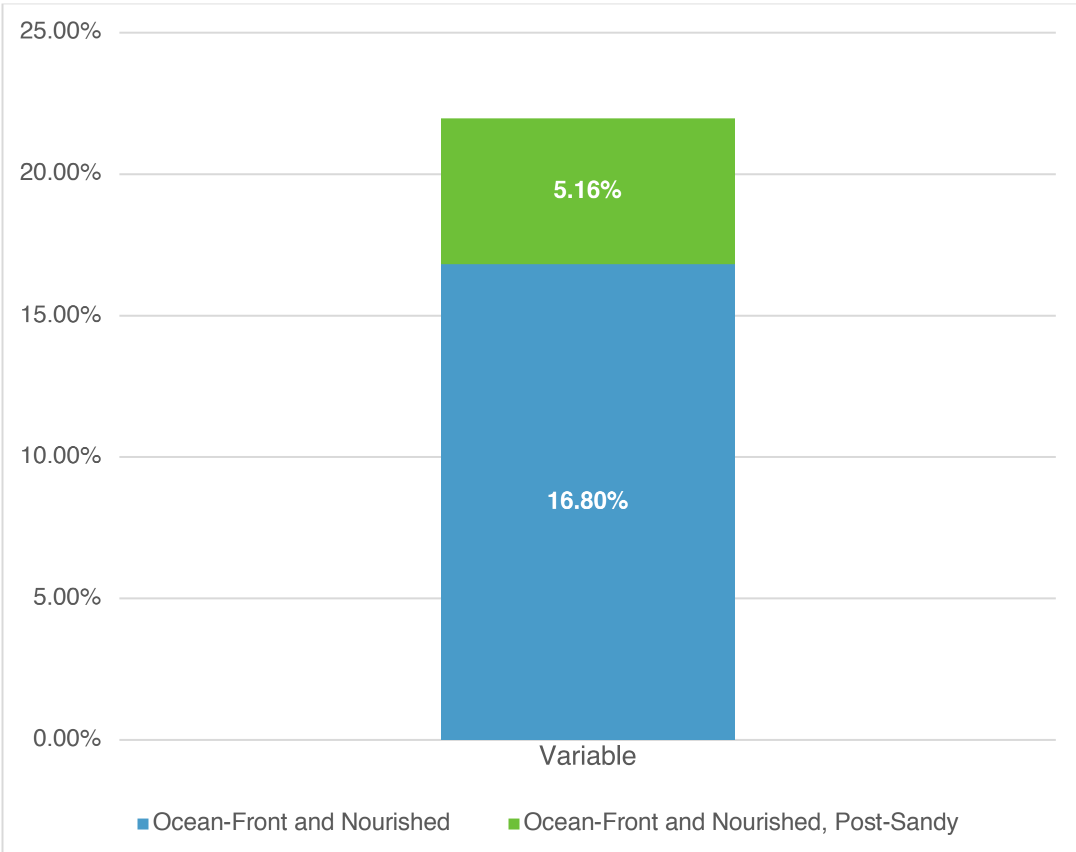


Table I: Summary statistics

Variables	Mean	Std. Dev	Min	Max
Sale Price ($)	376660.90	208967.10	15000	1900000.00
Number of bedrooms	3.96	1.31	1	10
Number of bathrooms	3.14	1.61	1	10
Built area (Sq. ft.)	2089.73	943.06	400	10697
Age	16.64	13.13	0	118
Number of stories	11.65	0.63	1.00	4.00
Elevation (ft.)	11.31	6.70	2.92	40.45
Distance to shore (10 m)	69.17	58.45	0.00	467.08
Ocean-front (%)	0.04	0.21	0	1
Sound-front (%)	0.01	0.10	0	1
Number of observations	**8474**			

Table II: Regression Results

Variables	**No Hurricane**	**Hurricane Sandy**	**Hurricane Arthur**
Bedroom	0.0321**	0.0299**	0.0322**
	(0.00980)	(0.0110)	(0.00983)
Story	0.120***	0.122***	0.120***
	(0.0142)	(0.0156)	(0.0141)
Sq. Feet	0.000170***	0.000175***	0.000170***
	(1.21e-05)	(1.33e-05)	(1.21e-05)
Bathroom	0.0286***	0.0235***	0.0285***
	(0.00579)	(0.00541)	(0.00576)
Ocean Front (OF)	0.238***	0.228***	0.238***
	(0.0397)	(0.0373)	(0.0401)
Sound Front (SF)	0.388***	0.387***	0.388***
	(0.0570)	(0.0561)	(0.0570)
Distance from Shore (10m)	-0.000649*	-0.000688*	-0.000649*
	(0.000293)	(0.000296)	(0.000293)
Age	-0.00481**	-0.00489**	-0.00481**
	(0.00152)	(0.00144)	(0.00152)
Elevation	-0.00613***	-0.00666***	-0.00613***
	(0.00116)	(0.00111)	(0.00116)
Living Shoreline	-0.0588**	-0.138***	-0.0580**
	(0.0227)	(0.0163)	(0.0210)
Nourishment	-0.0173	-0.0356**	-0.0180
	(0.0203)	(0.0102)	(0.0199)
OF & Nourished	0.181***	0.168***	0.203***
	(0.0193)	(0.0246)	(0.0141)
OF & Living	-0.163***	-0.146**	-0.161**
	(0.0396)	(0.0552)	(0.0516)
SF & Living	0.00321	0.00908	0.00926
	(0.0513)	(0.0521)	(0.0508)
OF & Nourished & Post-Arthur			-0.0153
			(0.0666)
OF & Living & Post-Arthur			-0.0976
			(0.0847)
SF & Living & Post-Arthur			-0.0269
			(0.0277)
OF & Nourished & Post-Sandy		0.0516*	
		(0.0257)	
SF & Living & Post-Sandy		0.00956	
		(0.0316)	
Constant	11.88***	11.92***	11.88***
	(0.1000)	(0.104)	(0.100)
City by Year Fixed Effects	Yes	Yes	Yes
Subdivision Fixed Effects	Yes	Yes	Yes
Observations	8,474	7,790	8,474
R-squared	0.631	0.628	0.631

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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